There are a lot of possible health effects due to non-ionizing radiation. Which direction research takes could determine the speed at which affirmative action takes place.

2018-Research directions:

RF-EMF Radiation Effects

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Acronyms:
Radiofrequency (RF), Alzheimer's Disease (AD), electromagnetic frequency (EMF), Reactive oxidative species (ROS), β-amyloid (Aβ), synaptic vesicles (SV), Electromagnetic hypersensitivity (EHS), and Idiopathic Environmental Intolerance (IEI)

The purpose of this review is to consider the current areas of RF-EMF research and observe the possible directions in which that research may be headed. Current studies are reviewing and observing environmental effects and measuring their current levels for RF. Many of the reviews are indicating that there is a risk of harm on both environmental and mammalian health effects. The available research on environmental impacts is variable as it often is observational and cannot depict causal effects only relational (correlation) effects. Much of the health impact research is conducted as rodent studies or in vitro as human studies are difficult to accomplish ethically.

At this time many studies have been completed or are underway to measure what RF environmental levels are compared to safety standards. Stockholm conducted a study in which the total mean level was 5,494 $\mu W/m^2$ and in high traffic areas up to a mean level of 10,728 $\mu W/m^2$. All measurements exceeded the 30-60 $\mu W/m^2$ target level based on non-thermal effects according to the Bioinitiative Report. The International Commission on Non-Ionizing Radiation Protection guideline established at 2-10 W/m^2 in 1998 and has not changed despite growing evidence of non-thermal biological effects as much lower levels. The environmental RF radiation levels are expected to increase with the introduction of 5G technologies (Carlberg *et al.*, 2019). Therefore, continuously monitoring these levels will be required in order to observe environmental changes.

The possible beneficial effects of RF-EMF on AD where the electromagnetic irradiation results in a suppression of Aβ deposition in brain cells and improves cognitive function for AD. It has been hypothesized that the observed increase in mitochondrial soluble Aβ peptide was caused by the ability of EMF to disaggregate Aβ-oligomers. It was also demonstrated that EMF-induced mitochondrial enhancement (the main site for ROS generation) occurred through non-thermal effects because brain temperatures were either stable or decreased during or after EMF- treatment (Tsoy *et al.*, 2019). RF-EMF has also been noted as having a beneficial effect in reducing production of plaques in advanced AD (Jeong *et al.*, 2015). There is an agreement that beneficial or not RF-EMF has a biological effect and the safety standards must be changed.

From current studies it is obvious that RF-EMF have deleterious effects on sperm parameters, affects the role of kinases in cellular metabolism and negative effects on the endocrine system. This may induce oxidative stress which increased levels of ROSs which may lead to infertility (Kesari *et al.*, 2018). The male fertility is not the only issue with this. If the cells are viable for reproduction, do they carry a risk of passing on damaged genes to the offspring? A single study that conducted this found that there was no risk associated with congenital malformation for the children of men whom have had cancer therapy but there is a risk associated with offspring malformations (Al-Jebari *et al.*, 2019), (Guo *et al.*, 2019). There is also an increased risk of premature birth in women

whom have had excessive exposure to RF radiation while pregnant (Singh *et al.*, 2018; Tsarna *et al.*, 2019).

There is strong evidence that RF-EMF influences the human EEG, while this has been repeatedly shown the underlying mechanism has not fully been explored. There is evidence that RF-EMF exposures are sufficient to engage a thermoregulatory response. This is consistent with an underlying thermal mechanism being responsible for the changes observed in brain physiology (Loughran *et al.*, 2019). This induces a thermal response within the brain tissue and needs to be explored further for long term health effects.

There has been another study suggesting that after RF-EMF exposure there is an observed decrease in dopamine concentration in the striatum which was caused by both a reduction in the number of dopaminergic neurons and in the number of SVs. This causes a difficult recovery after MPTP treatment (1-methyl-4-phenyl-1,2,3,6-tetrahydropyridine). This suggests that exposing the brain to RF-EMF caused a decrease in the number of SVs and dopaminergic neurons in the striatum. These primary changes impair the recovery of locomotor activities following MPTP damage to the striatum (Kim *et al.*, 2019). The brains ability to recover from stress is reduced and this could have long term effects such as brain tumor risks and much more research will be needed.

Of the many studies conducted the observed risks of cancer are among the most common. The connection between cell phone radiation and thyroid cancer is among these and there is evidence that exposure may negatively influence of uptake of iodine or increases temperature effect on the thyroid gland (Asl *et al.*, 2019). This area has plenty of research conducted, therefore the next step for this would be to use this information to change legislation and safety standards.

The development of new and un-categorizable illnesses such as EHS and IEI-EMF. The symptoms are difficult to categorize due to the nature of variability of symptoms between subjects. The current models for diagnosis are unable to quantify the causation of the illnesses and their validity for models are questionable (Dieudonne, 2019).The only nation to currently have a written suggestion guideline for the diagnosis and treatment of EHS is Austria. The need for an International Classification of the disease is necessary for both the diagnosis of the disease and preventative action and treatment (Hedendahl *et al.*, 2015). The effect and symptoms of neuropsychiatric effects are vast and variable; however, the conclusions drawn from the effects are clear. The ever-growing exposures should be viewed as a major threat to the human civilization. Current safety standards are based solely on the thermal effect and do not include the non-thermal effects despite their thorough testing. Therefore, the current safety standards have no scientific merit for legislation procedures (Pall, 2016).

There are many different aspects to research on health such as: health risks and their levels of danger, diagnosis, treatment, prevention, solutions for avoidance and many more. In this relatively underappreciated field, the entire spectrum will require more research in order to gain the foot hold in public knowledge and acceptance. Ethicality of

future research will limit testing as well as functionality. It would be unethical to expose individuals to possibly harmful test environments for the sake of a study. It is also impossible to have a control group without locking them in a faraday cage for the duration of the study.

The current areas of study consist of cellular mechanism obstructions or changes, in other words cancers and neurological affects. The current studies on human beings are mostly all observational and speculative. Current studies are still reviewing and observing environmental levels and the effects on health. The majority of the reviews are pointing into the direction of harm. The science has determined that RF-EMF is harmful for the average human being. Future research will likely stem from this and begin looking at, as treatments emerge, their effectiveness. When what would be beneficial is if it looks at methods of change and their effectiveness. Also review of the technologies and find ways to make them less harmful to everything and everyone involved while maintaining their function and efficiency.

There are a few directions that research can take in the future. Firstly, RF-EMF radiation needs to be classified as a serious danger to human health. Next, the need for a standardized measurement device to quantify levels will be required. Then knowing the possible health effects and what to watch out for in regard to symptoms to aid in the diagnosis of ailments associated with the radiation. Finally, mitigation techniques as well as a possible alternative solution to communication techniques that does not cause negative health effects.

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